# SECTION I.—AEROLOGY.

## SOLAR AND SKY RADIATION MEASUREMENTS DURING NOVEMBER, 1918.

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[Dated: Weather Bureau, Washington, D. C., Dec. 30, 1918.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1918, 46:2.

The monthly means and departures from normal values in Table 1 show that direct solar radiation intensities measured slightly above normal at Madison, Wis., and slightly below normal at Washington, D. C., and Lincoln, Nebr. No measurements were obtained at Santa Fe, N. Mex., on account of a defect in the galvanometer.

On the 29th, extrapolation of the measurements obtained at Washington, Madison, and Lincoln to zero air mass gives, respectively, 1.71, 1.72, and 1.73 calories per minute per cm.² The agreement in these values is very close, especially when we take into account the vapor pressure at the three stations, as shown by the data in Table 2.

Table 3 shows a deficit of radiation at all three stations, amounting to 7 per cent of the November normal at Washington, 8 per cent at Madison, and 6 per cent at Lincoln.

Skylight polarization measurements made at Washington on 7 days give a mean of 59 per cent, and a maximum of 64 per cent on the 6th. This latter is below the average maximum for November at Washington. Measurements obtained at Madison on 9 days give a mean of 66 per cent and a maximum of 73 per cent on the 12th.

TABLE 1.—*Solar radiation intensities during November, 1918.*

[Gram-calories per minute per square centimeter of normal surface.]

**Washington, D. C.**

| Date. | Sun's zenith distance. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
| | Air mass. | | | | | | | | | |
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| A. M. | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| Nov. 1 | | | | 1.08 | 0.98 | 0.88 | 0.80 | | | |
| 2 | | 1.15 | 1.04 | 0.94 | 0.79 | | | | | |
| 6 | | 1.25 | 1.13 | 1.08 | 1.04 | 0.99 | 0.93 | 0.91 | 0.87 | |
| 7 | [*1.36] | 1.29 | 1.21 | 1.12 | 1.05 | 0.99 | | | | |
| 8 | | | 0.90 | 0.77 | 0.67 | | | | | |
| 11 | | | 1.29 | 1.21 | 1.13 | 1.06 | 0.99 | 0.93 | 0.37 | |
| 13 | | | 1.08 | 1.00 | 0.92 | 0.82 | | | | |
| 14 | | | 1.03 | 0.93 | 0.81 | 0.73 | 0.66 | | | |
| 19 | | | | 1.20 | 1.14 | 1.07 | 1.00 | 0.93 | 0.88 | 0.82 |
| 27 | | | | 1.03 | 0.96 | 0.91 | 0.87 | | | |
| 29 | [*1.45] | | | 1.22 | 1.14 | 1.06 | 1.00 | 0.93 | 0.90 | |
| 30 | | | 1.27 | 1.17 | 1.07 | 0.99 | 0.93 | 0.87 | 0.82 | |
| Monthly means | | 1.23 | 1.12 | 1.06 | 0.98 | 0.95 | 0.90 | 0.91 | 0.87 | (0.82) |
| Departure from 11-year normal | | −0.12 | −0.06 | −0.02 | −0.03 | +0.05 | +0.04 | +0.09 | +0.10 | +0.11 |
| P. M. | | | | | | | | | | |
| Nov. 6 | | | 1.12 | 0.96 | | | 0.66 | | 0.60 | |
| 12 | | | 0.94 | 0.89 | 0.85 | 0.69 | 0.65 | 0.60 | 0.56 | 0.52 |
| 13 | | | 0.96 | 0.91 | 0.74 | 0.64 | 0.57 | 0.51 | 0.47 | |
| 14 | | | 1.06 | 1.01 | 0.92 | 0.80 | 0.70 | 0.64 | | |
| 26 | | | 1.27 | 1.19 | | | | | | |
| 27 | | | | 1.05 | 1.00 | 0.95 | | | | |
| 29 | | | 1.26 | 1.17 | 1.07 | | | | 0.80 | |
| 30 | | | | | 1.17 | 1.07 | 1.03 | 0.98 | 0.94 | |
| Monthly means | | | 1.10 | 1.03 | 0.96 | 0.83 | 0.72 | 0.68 | 0.67 | (0.52) |
| Departure from 11-year normal | | | −0.07 | −0.05 | −0.01 | −0.06 | −0.09 | −0.08 | −0.05 | −0.16 |

* Extrapolated, and reduced to mean solar distance.

TABLE 1.—*Solar radiation intensities during November, 1918*—Continued.

| Date. | Sun's zenith distance. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0° | 48.3° | 60.0° | 65.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
| | Air mass. | | | | | | | | | |
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| A. M. | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| **Madison, Wis.** | | | | | | | | | | |
| A. M. | | | | | | | | | | |
| Nov. 12 | | | | | 1.19 | | | | | |
| 13 | | | 1.39 | 1.32 | 1.25 | 1.19 | 1.12 | 1.06 | 1.02 | |
| 14 | | | | 1.01 | 0.97 | 0.90 | 0.80 | 0.71 | 0.64 | |
| 23 | | | | 1.37 | 1.27 | 1.19 | 1.12 | 1.05 | 0.98 | 0.93 |
| 25 | | | | 1.33 | 1.25 | 1.17 | 1.10 | 1.01 | 0.97 | 0.90 |
| 26 | | | | 1.25 | 1.17 | 1.09 | 1.01 | 0.93 | | |
| 27 | | | | 1.33 | 1.24 | 1.15 | 1.02 | 0.97 | 0.92 | 0.86 |
| 29 | [*1.54] | | | 1.34 | 1.27 | 1.20 | 1.13 | 1.05 | 1.02 | 0.98 |
| Monthly means | | | (1.39) | 1.28 | 1.20 | 1.13 | 1.04 | 0.97 | 0.92 | 0.92 |
| Departure from 9-year normal | | | +0.09 | +0.06 | +0.04 | −0.01 | +0.01 | ±0.00 | +0.05 | +0.11 |
| P. M. | | | | | | | | | | |
| Nov. 8 | | | | | 1.09 | | | | | |
| 12 | | | | 1.32 | | | | | | |
| 13 | | | | 1.26 | 1.22 | | | | | |
| 14 | | | | 1.10 | 1.00 | 0.92 | | | | |
| 23 | | | | | | 1.17 | | | | |
| 25 | | | | 1.26 | 1.21 | | | | | |
| 27 | | | | 1.30 | | | | | | |
| 29 | | | | 1.35 | | | 1.15 | | | |
| Monthly means | | | | 1.26 | 1.13 | (1.04) | (1.15) | | | |
| Departure from 9-year normal | | | | +0.02 | −0.03 | +0.01 | | | | |
| **Lincoln, Nebr.** | | | | | | | | | | |
| A. M. | | | | | | | | | | |
| Nov. 1 | | | 1.32 | 1.23 | | | | | 0.92 | 0.86 |
| 2 | | | 1.29 | 1.18 | 1.09 | 1.01 | | | | |
| 3 | [*1.55] | | 1.36 | 1.26 | 1.17 | | | | | |
| 8 | | | 1.28 | 1.17 | | | | | | |
| 9 | [*1.61] | | 1.42 | 1.33 | 1.24 | 1.16 | | | | |
| 11 | | | | | 1.17 | 1.09 | | | | |
| 13 | [*1.49] | | 1.36 | | 1.16 | | | | | |
| 18 | [*1.58] | | 1.42 | 1.30 | | | | | | |
| 19 | [*1.48] | | 1.34 | 1.25 | 1.22 | 1.13 | | | | |
| 25 | | | | 1.22 | | | | | | |
| 29 | [*1.49] | | | 1.29 | 1.22 | | 1.07 | | | |
| Monthly means | | | 1.35 | 1.25 | 1.18 | 1.10 | (1.07) | | (0.92) | (0.86) |
| Departure from 4-year normal | | | −0.01 | −0.05 | −0.05 | −0.03 | ±0.00 | | −0.07 | −0.13 |
| P. M. | | | | | | | | | | |
| Nov. 1 | | | | 1.17 | 1.09 | 1.02 | 0.96 | 0.90 | 0.84 | 0.79 |
| 3 | | | 1.36 | 1.26 | 1.17 | 1.09 | 1.02 | | 0.88 | 0.82 |
| 9 | | | 1.41 | 1.32 | 1.24 | 1.16 | 1.09 | 1.03 | 0.97 | 0.92 |
| 13 | | | 1.32 | 1.23 | 1.14 | 1.06 | 0.99 | 0.92 | 0.86 | 0.80 |
| 18 | | | 1.42 | 1.35 | 1.28 | 1.22 | 1.16 | 1.10 | | |
| 19 | | | 1.35 | 1.26 | 1.18 | 1.10 | 1.04 | 0.98 | 0.92 | 0.87 |
| 26 | | | 1.27 | 1.19 | | | | | | |
| 29 | | | | 1.31 | 1.22 | 1.16 | 1.11 | 1.05 | 0.99 | 0.93 |
| 30 | | | 1.36 | 1.28 | 1.21 | 1.10 | | | | |
| Monthly means | | | 1.36 | 1.26 | 1.19 | 1.11 | 1.05 | 1.00 | 0.91 | 0.86 |
| Departure from 4-year normal | | | −0.03 | −0.02 | −0.02 | −0.01 | −0.01 | ±0.00 | −0.02 | −0.05 |

* Extrapolated, and reduced to mean solar distance.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

| Washington, D. C. | | | Madison, Wis. | | | Lincoln, Nebr. | | |
|---|---|---|---|---|---|---|---|---|
| Date. | 8 a.m. | 8 p.m. | Date. | 8 a.m. | 8 p.m. | Date. | 8 a.m. | 8 p.m. |
| 1918. | *mm.* | *mm.* | 1918. | *mm.* | *mm.* | 1918. | *mm.* | *mm.* |
| Nov. 1 | 4.57 | 3.81 | Nov. 8 | 8.48 | 6.50 | Nov. 1 | 3.63 | 7.57 |
| 2 | 4.75 | 3.45 | 12 | 4.75 | 2.74 | 2 | 3.99 | 9.47 |
| 6 | 4.57 | 4.75 | 13 | 3.30 | 3.00 | 3 | 5.79 | 7.04 |
| 7 | 4.57 | 6.02 | 14 | 3.81 | 6.50 | 8 | 4.57 | 4.37 |
| 8 | 5.79 | 7.57 | 23 | 1.96 | 2.49 | 9 | 3.63 | 5.36 |
| 11 | 3.81 | 3.99 | 25 | 2.49 | 2.87 | 11 | 5.56 | 8.48 |
| 12 | 3.63 | 4.57 | 26 | 3.15 | 2.36 | 13 | 3.99 | 7.29 |
| 13 | 4.57 | 5.36 | 27 | 2.49 | 3.45 | 18 | 3.30 | 4.37 |
| 14 | 3.30 | 3.81 | 29 | 2.87 | 2.49 | 19 | 3.45 | 5.79 |
| 19 | 5.79 | 6.50 | | | | 25 | 2.74 | 3.45 |
| 26 | 2.87 | 3.63 | | | | 29 | 1.96 | 3.63 |
| 27 | 2.87 | 3.99 | | | | 30 | 2.16 | 4.57 |
| 29 | 6.02 | 3.81 | | | | | | |
| 30 | 3.30 | 2.49 | | | | | | |

TABLE 3.—*Daily totals and departures of solar and sky radiation during November, 1918.*

[Gram-calories per square centimeter of horizontal surface.]

| Day of month. | Daily totals. | | | Departures from normal. | | | Excess or deficiency since first of month. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Washington. | Madison. | Lincoln. | Washington. | Madison. | Lincoln. | Washington. | Madison. | Lincoln. |
| | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| Nov. 1 | 183 | 277 | 354 | − 75 | 84 | 97 | − 75 | 84 | 97 |
| 2 | 217 | 152 | 332 | − 39 | − 39 | 78 | −114 | 45 | 175 |
| 3 | 308 | 51 | 338 | 54 | −137 | 87 | − 60 | − 92 | 262 |
| 4 | 217 | 196 | 235 | − 35 | 10 | − 13 | − 95 | − 82 | 249 |
| 5 | 203 | 214 | 47 | − 47 | 30 | −198 | −142 | − 52 | 51 |
| 6 | 304 | 208 | 78 | 57 | 27 | −165 | − 85 | − 25 | −114 |
| 7 | 290 | 60 | 44 | 47 | −119 | −196 | − 38 | −144 | −310 |
| 8 | 242 | 160 | 306 | 2 | − 16 | 69 | − 36 | −160 | −241 |
| 9 | 72 | 57 | 353 | −164 | −117 | 118 | −200 | −277 | −123 |
| 10 | 284 | 213 | 292 | 51 | 42 | 60 | −149 | −235 | − 63 |
| 11 | 315 | 226 | 309 | 86 | 57 | 79 | − 63 | −178 | 16 |
| 12 | 284 | 241 | 316 | 58 | 75 | 88 | − 5 | −103 | 104 |
| 13 | 258 | 242 | 275 | 36 | 78 | 49 | 31 | − 25 | 153 |
| 14 | 254 | 207 | 160 | 35 | 46 | − 64 | 66 | 21 | 89 |
| 15 | 232 | 55 | 49 | 16 | −103 | −173 | 82 | − 82 | − 84 |
| 16 | 156 | 23 | 52 | − 57 | −133 | −167 | 25 | −215 | −251 |
| 17 | 32 | 36 | 48 | −178 | −117 | −169 | −153 | −332 | −420 |
| 18 | 127 | 30 | 320 | − 80 | −121 | 105 | −233 | −453 | −315 |
| 19 | 192 | 45 | 301 | − 12 | −103 | 88 | −245 | −556 | −227 |
| 20 | 115 | 53 | 58 | − 86 | − 93 | −153 | −331 | −649 | −380 |
| Decade departure | | | | | | | −182 | −414 | −317 |
| 21 | 86 | 39 | 46 | −112 | −104 | −163 | −443 | −753 | −543 |
| 22 | 131 | 180 | 91 | − 64 | 39 | −116 | −507 | −714 | −659 |
| 23 | 191 | 212 | 131 | − 1 | 73 | − 74 | −508 | −641 | −733 |
| 24 | 165 | 220 | 252 | − 25 | 83 | 49 | −533 | −558 | −684 |
| 25 | 208 | 202 | 256 | 21 | 67 | 55 | −512 | −491 | −629 |
| 26 | 230 | 197 | 277 | 46 | 63 | 78 | −466 | −428 | −551 |
| 27 | 235 | 199 | 88 | 53 | 66 | −109 | −413 | −362 | −660 |
| 28 | 36 | 11 | 291 | −144 | −121 | 96 | −557 | −483 | −564 |
| 29 | 234 | 199 | 275 | 57 | 68 | 82 | −500 | −415 | −482 |
| 30 | 238 | 190 | 258 | 63 | 60 | 67 | −437 | −355 | −415 |
| Decade departure | | | | | | | −106 | +294 | −35 |
| Excess or deficiency since first of year: gr.-cal. | | | | | | | −3211 | +154 | −550 |
| Excess or deficiency since first of year: per cent. | | | | | | | − 2.6 | +0.1 | −0.4 |

## SOME CHARACTERISTICS OF THE MARVIN PYRHELIOMETER.

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[Abstract.]

This pyrheliometer is dynamic in type, in that it is necessary to consider the rate at which the receiver gains heat when exposed to radiation and the rate at which the receiver loses heat when shaded from radiation.

The essential feature of the instrument is the receiver. In the form used in the present work it consisted of a silver disk about 4.5 cm. in diameter and 0.3 cm. thick, in an annular space inside of which is carefully mounted with the best possible thermal contact a noninductive spirally wound coil of No. 35 silk insulated nickel wire in the form of a 3-lead resistance thermometer, having a total resistance of from 20 to 25 ohms. The coil serves both as the thermometer and as the heater for the purpose of an electrical calibration, the rise in temperature of the thermometer being observed when a known amount of electrical energy is dissipated in the coil. The receiver is mounted within a metal shell, which is incased by a wooden shell in order to reduce local temperature variations to a minimum, and the type of suspension of the receiver is such that thermal losses by conduction are negligible. Before the front face of the receiver a limiting diaphragm is placed, and leading from this, through a hole in the metal and wooden shells, is a diaphragmed and blackened tube which serves the purpose of limiting the cone of rays to a convenient solid angle greater than that subtended by the sun. The end of the tube carries a double-walled aluminum shutter, operated by a magnetic release controlled by a chronograph, which may be so set as to open or close the shutter at any desired instant. For solar work the instrument is mounted as an equatorial telescope and is driven by clockwork, so that the surface of the receiver is always presented normally to the sun.

The determination of the relation between the temperature of the thermometer and its resistance requires an independent experiment in which the receiver is removed from the pyrheliometer and mounted in a constant temperature bath, the temperature of which may be varied over the range required. The temperature relation so found may be accurately expressed by a parabolic equation, and for silver block No. III, which was employed in the present investigation, $R = 19.521 + 0.08394t + 0.00010127t^2$, where $t$ is the temperature centigrade. These data were obtained by Prof. H. H. Kimball, of the United States Weather Bureau.

The electrical calibration was made by subjecting the nickel coil of the thermometer to a measured current and observing the change in temperature indicated by the thermometer. The radiometric calibration was made in a similar manner except that the heat was supplied by radiation from an outside source. The source employed was a Lummer-Kurlbaum black body, or a black body of similar type, electrically heated, with a compensating winding to reduce the temperature gradient and to approximate temperature uniformity. The temperature of the inner inclosure, from which the radiation was taken, was measured by standard platinum, platinum-rhodium thermocouples, accurately calibrated in terms of the melting points of zinc (419.4°), antimony (630.5°), and copper (1083°). A water-cooled diaphragm was mounted directly in front of the opening to the furnace. This diaphragm acts as the effective source of radiation. The equation of rate of energy transfer from the furnace to the pyrheliometer receiver is as follows when $R$ is large compared with $\sqrt{A_1}$ and $\sqrt{A_2}$.

$$J = \frac{\sigma}{\pi}\left(T^4 - T_0^4\right)\frac{A_1 A_2}{R^2}$$

where $J$ = energy transferred per unit time from furnace to receiver.

$A_1$ = area of water cooled diaphragm in front of furnace.

$A_2$ = area of inmost or effective diaphragm in the pyrheliometer.

$T$ = absolute temperature of furnace.

$T_0$ = absolute temperature of pyrheliometer receiver and surroundings.

$\sigma$ = the Stefan-Boltzmann coefficient of radiation.

$R$ = distance from $A_1$ to $A_2$.